LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA22 | Whittington to Handsacre

Flood risk assessment (WR-003-022)

Water resources

November 2013

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Department for Transport

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Appendix WR-003-022

Environmental topic:	Water resources and flood risk assessment	WR
Appendix name:	Flood risk assessment	003
Community forum area:	Whittington to Handsacre	022

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise of four parts. The first of these is a route-wide appendix (Appendix WR-001-000).

1.1.2 Three specific appendices for each community forum area (CFA) are also provided. For the Whittington to Handsacre area (CFA22) these are:

- a water resources assessment (Appendix WR-002-022); and
- a Flood Risk Assessment (FRA) i.e. this appendix; and
- a river modelling report (Appendix WR-004-015).

1.1.3 Maps referred to throughout the water resources and FRA appendices are contained in the Volume 5 Water resources Map Book.

1.2 Scope of this assessment

1.2.1 This FRA considers the assessment of flood risk in this study area, which is defined as the area within 1km of the route within CFA22. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1], which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

1.2.2 This FRA presents baseline (current day) flood risk and post-construction flood risk as a result of the Proposed Scheme and has been written to demonstrate the relative change in flood risk as a result of the Proposed Scheme. Whilst all change in risk status is highlighted, the focus of the document is on the change in risk status to local receptors, particularly existing infrastructure.

1.2.3 A risk-based methodology has been adopted through the application of the source-pathway-receptor model. This model has been used to identify the cause of 'sources' of flooding to and from a development. The identification is based on a review of local conditions and consideration of the effects of climate change.

1.2.4 In order for there to be a flood risk, all the elements of the model (a flood source, a pathway and a receptor) must be present. Furthermore, effective mitigation can be provided by removing one element of the model, for example by removing the pathway or receptor.

1.2.5 Receptors may include people and their properties, business and infrastructure, and the built and natural environment within the range of the flood source which are connected to the source of flooding by a pathway.

[1] Department for Communities and Local Government (2012), *National Planning Policy Framework.*

1.2.6 This FRA has been completed to inform the Environmental Statement (ES) for the works, which will be a key part of the hybrid Bill submission required for the Proposed Scheme. The hybrid Bill is necessary for powers to build the railway, powers to buy land and for planning consent.

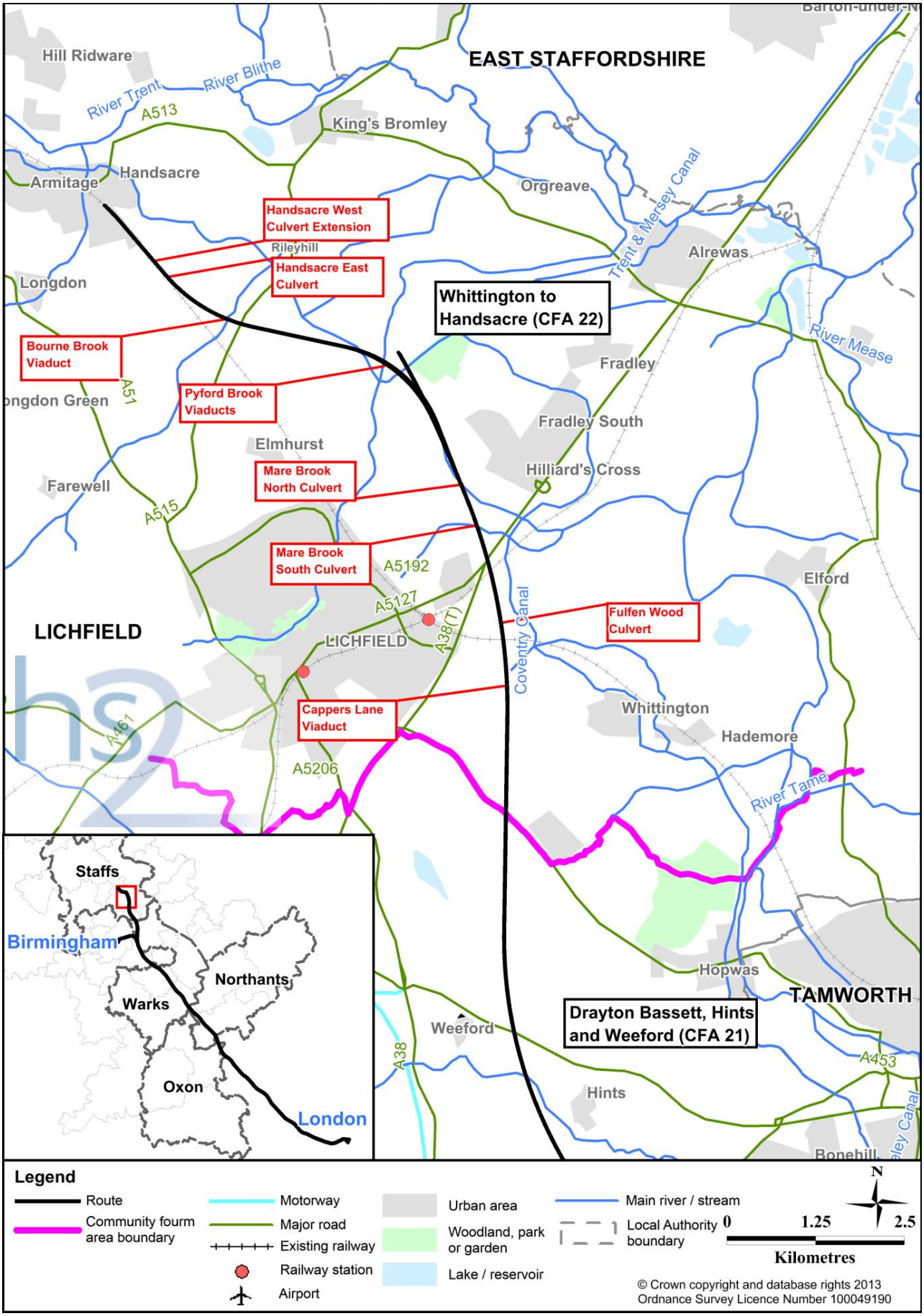
1.2.7 The Proposed Scheme will cross numerous surface water features within this study area, which are the Mare Brook, Curborough Brook, Bourne Brook and associated tributaries, including tributaries of the River Trent.

1.3 Location

1.3.1 In this FRA, the study area covers an 11.9km section of the Proposed Scheme in Staffordshire, where it passes to the east of Lichfield. It extends from the A51 in the south at Whittington Heath, passing over the A38 east of Lichfield and up to Handsacre in the north. The study area includes land within the communities of Whittington, Lichfield, Fradley South, Alrewas, Kings Bromley and Handsacre.

1.3.2 A location plan of the Proposed Scheme within this study area is shown on Figure 1.

Figure 1: Location plan



2 Flood risk assessment methodology

2.1 Source-pathway-receptor model

2.1.1 Flood risk is assessed using the source-pathway-receptor model. In this model, individual sources of flooding within the study area are identified. The primary source of flooding is rainfall, which is a direct source in the short term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewers) in the short or medium term. Stored rainfall, either naturally in aquifers (groundwater) and natural lakes or artificially impounded reservoirs and canals can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea. However, given the inland location of this study area, this final source of flooding does not pose a risk.

2.1.2 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. The associated risk magnitude is then categorised.

2.1.3 In general, receptors considered in this assessment include the Proposed Scheme and existing development within 1km of the route. However, any receptors beyond this where a significant impact was expected were considered in this assessment. The Proposed Scheme includes all associated temporary and permanent infrastructure. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified, mitigation is required as part of the design to prevent an increase in flood risk in line with recommendations in the NPPF.

2.1.4 The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.1.5 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the scheme has any potential to influence or alter the risk of flooding to each receptor. The Proposed Scheme will ensure that there is no adverse effect on the risk of flooding to third party receptors, and therefore, where such potential exists, mitigation is proposed based on further analysis.

2.1.6 The FRA defines the baseline flood risk and vulnerability of receptors. This is used to define the value, importance and significance of effects which is provided within the ES.

2.2 Flood risk categories

2.2.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

[2] Department for Communities and Local Government (2012), *National Planning Policy Framework Technical Guidance*.

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Watercourse[3]		Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water/ overland flow[4]	No FMfSW	FMfSW <0.3m for 1 in 200 year event	FMfSW >0.3m for 1 in 200 year event and FMfSW <0.3m for 1 in 30 year event	FMfSW >0.3m for 1 in 30 year event	
Groundwater[5]		Very low-low	Moderate	High-very high	
Drainage and sewer systems[6]	No sewer in vicinity of site	Surcharge point >20m from site and no pathways	Surcharge point within 20m of site and restricted pathways	Sewer network crosses site and pathways exist	
Artificial sources[7]	Outside of inundation mapping / no pathway exists	Within inundation mapping / pathway exists			

2.3 National planning policy framework

2.3.1 This assessment of flood risk makes use of the NPPF which is the Government's planning policy in relation to development and flood risk. It is set out within the NPPF that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk, but where development is necessary, making it safe without increasing flood risk elsewhere. The NPPF requires that proposed development located within Flood Zones 2 and 3 is assessed in relation to flood risk. This includes both flood risk to the development and any increases in flood risk elsewhere as a result of the development, with an allowance for climate change.

2.3.2 Methods used to ensure that development is at the lowest possible risk and that the development is safe without causing an increased risk elsewhere includes the application of the Sequential and Exception Tests. However, the Sequential Test has been considered as part of the overview FRA for the Proposed Scheme presented in Volume 3 of the ES and hence has not been repeated in this FRA.

Flood zone classification

2.3.3 The NPPF splits the Environment Agency's Flood Map into three separate Flood Zones. These Flood Zones should be used in determining the appropriateness of proposed development uses and they represent flooding without flood defences in place.

[3] River flood risk taken from the Environment Agency Flood Zone mapping or hydraulic modelling carried out for this FRA.
[4] Surface water flood risk taken from the Environment Agency Flood Maps for Surface Water (FMfSW).
[5] Groundwater flood risk taken from local flood risk assessment reports.
[6] Identified using the Severn Trent Water's assets network and the South Staffordshire Water's assets network.
[7] Risk from reservoir flooding identified using the Environment Agency reservoir inundation mapping, canal flooding taken from identifying proximity of the Proposed Scheme to canals from Ordnance Survey mapping.

2.3.4 The Flood Zones are defined as:

- Flood Zone 1 – Areas with a 'low probability' of flooding and where the annual probability of flooding is lower than 0.1% for either river or sea flooding. The NPPF imposes no constraints upon the type of development within Flood Zone 1;
- Flood Zone 2 – Areas with a 'medium probability' of flooding and where the annual probability of flooding is between 0.1 and 1.0% for river flooding or between 0.5 and 0.1% for sea flooding. The NPPF recommends that Flood Zone 2 is suitable for most types of development with the exception of 'highly vulnerable' land uses; and
- Flood Zone 3 – Areas with a 'high probability' of flooding and where the annual probability of flooding is 1.0% or greater for river flooding or 0.5% or greater for sea flooding. The NPPF recommends that appropriate development is based upon a further classification of Flood Zone 3: 3a high probability and 3b functional floodplain (where water has to flow or be stored in times of flood).

2.4 Local flooding planning policy documents

2.4.1 The local policies for this study area with implication in relation to flood risk are:

- Lichfield District Local Plan 1998[8] – Policy E15. Policy E15 states that flood protection will not generally support development in areas at risk of flooding, unless suitable preventative measures are undertaken. The policy states that development that would result in the loss of maintenance access to watercourses, the loss of natural floodplain, in adverse effects on river defences, or in substantial changes in the characteristics of surface water run-off, will not be permitted.

2.4.2 The Lichfield District Council Strategic Flood Risk Assessment (SFRA)[9] and the Staffordshire Preliminary Flood Risk Assessment (PFRA)[10] aids the Council in preparing sustainable policies for the long-term management of flood risk and improving existing emergency planning procedures. The SFRA is used as an evidence base to promote the location of future development primarily in low flood risk areas. This SFRA has been used to inform this FRA.

2.5 Historical sources of flooding

2.5.1 The historical flooding which has occurred either at the location of the route or in close proximity have been determined as part of this FRA. These areas of historical flooding have been identified because places which have flooded in the past may be more susceptible to flooding in the future. Two sources of data relating to historical flooding have been used: local authority information (the relevant SFRA and PFRA) and extents of historical sources of river flooding as provided by the Environment Agency.

[8] Lichfield District Council (1998), *Lichfield District Local Plan*.
[9] Lichfield District Council (2008), *Lichfield Strategic Flood Risk Assessment*. Completed by Halcrow Group Ltd.
[10] Staffordshire County Council (2011), Staffordshire Preliminary Flood Risk Assessment. Completed by Royal Haskoning on behalf of Staffordshire County Council.

2.6 Flood risk approach

River flooding approach

Crossing locations

2.6.1 To determine the river flood risk at locations where the route will cross watercourses and to identify any changes in flood risk as a result of the Proposed Scheme, either existing hydraulic models have been used where available or new hydraulic models have been constructed. Where new models were required flows have been determined in line with current flood estimation guidelines[11].

Flow estimation

2.6.2 The watercourses which will be crossed by the route within this study area have no known detailed modelling available. Where Flood Zones are associated with these watercourses, the outlines have been determined through the use of broadscale topographic data, which are considered to be a rough guide when determining areas at risk of flooding and hence have not be used for the design of engineering works. There are other watercourses which have no associated Flood Zones. Flows for these watercourses, at the location of the proposed crossings, have been determined for the 1 in 20 (5%), 1 in 100 (1%), 1 in 100 (1%) with a 20% allowance for climate change and 1 in 1000 (0.1%) annual probability events.

2.6.3 A quick estimation of flow was produced at the crossing locations using the Revitalised Flood Hydrograph model (ReFH) where the contributing catchments were represented within the Flood Estimation Handbook (FEH) CD-ROM[12]. A FEH calculation record for the estimation of flow using ReFH is provided in the river modelling report (Volume 5, WR-004-015).

2.6.4 Small catchments (normally less than approximately 0.5km^2), such as at the two River Trent tributaries (SWC-CFA22-017; SWC-CFA22-018), are not represented on the FEH CD-ROM and hence it is not possible to either produce a catchment boundary or determine catchment descriptors (required for the estimation of flow) from this source. For crossings where the watercourse is not represented within the FEH CD-ROM, a scaling method based on area, in line with the flood estimation guidelines was carried out. Contributing catchment areas at crossing locations were determined using topographic and Ordnance Survey (OS) mapping; in areas of uncertainty slightly larger catchments were defined as a conservative approach. The flows estimated through the use of ReFH for catchments in the northern study areas of the Proposed Scheme were used to determine a scaling factor. The greatest flow per km^2 was used as a scaling factor for the catchments in this study area which were manually determined. An error allowance of 10% was also applied to reduce the risk of underestimating flows.

Modelling approach

2.6.5 Suitable hydraulic models were not available at all crossings and so new hydraulic models were built utilising the high resolution Light Detection and Ranging (LiDAR)

[11] Environment Agency (2012), *Flood estimation guidelines*.
[12] Centre for Ecology and Hydrology (2009), *FEH CD-ROM Version 3*, ©NERC (CEH).

data provided for the Proposed Scheme. Further detail in relation to the hydraulic modelling is included in the river modelling report (Volume 5, WR-004-015).

2.6.6 There are several road embankments and other raised infrastructure across the watercourses which will potentially provide constriction to flows. The modelled Digital Terrain Model (DTM) had to be modified to allow for flows through culverts underneath these embankments. In the absence of any survey data of these road embankment culverts, a channel opening of 5m was incorporated at each of these embankments.

2.6.7 The inflow boundaries were mostly applied as steady state flows with unsteady state flows applied for certain watercourses. For watercourses with floodplain attenuation such as ponds and lakes or significant obstructions to flow (e.g. due to embankments), the inflows were modelled using unsteady state hydrographs. These models were run at longer durations covering the period of the hydrograph and attenuation. The resulting baseline (current) models were run for the 1 in 100 (1%) annual probability with an allowance climate change and 1 in 1000 (0.1%) events over a range of durations depending upon the flow conditions.

2.6.8 The Proposed Scheme models included either viaducts or culverts depending on the scheme design. The railway embankments were represented by modifying the modelled DTM at those locations. The 1 in 100 (1%) annual probability with an allowance for climate change peak flood levels upstream of the crossings were compared to the baseline (current) levels to assess the change in flood risk. The 1 in 1000 (0.1%) annual probability peak levels were extracted to inform the vertical alignment of the track.

River flood risk elsewhere along the route

2.6.9 In addition to watercourse crossings, there are sections of the route which are located in areas potentially at risk of river flooding. These areas have been identified through the use of the Environment Agency Flood Zone mapping. This mapping has been used in preference to SFRA mapping as it is considered more up to date and hence likely to best reflect areas at risk. River flood risk to these sections of the route needs to be determined both to prevent an unacceptable risk to the Proposed Scheme and to prevent it increasing flood risk as result of a reduction in floodplain storage.

Summary of river flooding approach

2.6.10 Due to the number of river crossings, varying complexities, and the amount of data and information available for each, at some locations the modelling approach is highly specific. These locations have been reported as such and further information is included in the river modelling report (Volume 5, WR-004-015).

Surface water flood risk

2.6.11 The baseline (current) assessment of surface water flood risk was completed using the Flood Maps for Surface Water (FMfSW). The maps utilised for this assessment are listed as:

- 1 in 30 (3.3%) annual probability and surface water flooding greater than 0.1m deep;

- 1 in 30 (3.3%) annual probability and surface water flooding greater than 0.3m deep;
- 1 in 200 (0.5%) annual probability and surface water flooding greater than 0.1m deep; and
- 1 in 200 (0.5%) annual probability and surface water flooding greater than 0.3m deep.

2.6.12 This mapping identified sections of the route which currently are at specific risk from surface water flooding. The risk classification assigned at each location is dependent on which FMfSW the receptor is located within.

2.6.13 The Proposed Scheme has the potential to interrupt surface water flow which would require mitigation to prevent an increase in flood risk. In addition, other design elements such as landscaping will alter the permeability of the ground and hence modify sections of the surface water catchments. The assessment involved determining the land drainage catchments, surface water run-off from these catchments and the capacity of Sustainable Drainage Systems (SuDS) and culverts.

2.6.14 Land drainage catchments were identified using topographic data (primarily 5m contours, or 1m contours on small or unclear catchments). The assumption was made that linear features such as roads and railways do not act as a cut off for overland flow.

2.6.15 The calculation of Greenfield run-off rates from existing catchments was undertaken using the online SuDS tool[13]. A growth factor of 30% was applied to the 1 in 100 (1%) annual probability rainfall event to determine the flow during this event with an allowance for climate change. A factor of 62% (based on calculations using the Flood Studies Supplementary Report 14[14]) was applied to the 1 in 100 (1%) annual probability rainfall event to determine the flow during the 1 in 1000 (0.1%) annual probability event.

2.6.16 Run-off from modified sections of the catchment as a result of the Proposed Scheme (e.g. landscape areas) which alter the permeability were determined using the Institute of Hydrology 124[15] methodology with a value of 0.5 for the soil parameter and a safety factor of 1.2.

2.6.17 Storage volumes were calculated using the online SuDS tool assuming that landscape areas will be impermeable. The storage volumes required were taken to be the sum of the attenuation and long term storage as a conservative approach.

2.6.18 The calculations for the proposed drainage design have been completed in line with the requirements in Volume 1, Section 9.

Groundwater flood risk

2.6.19 Groundwater bodies and aquifers present within a 1km buffer of the route have been identified and named on available web-based mapping data provided for the purposes of the Proposed Scheme.

[13] HR Wallingford (2013), UK Sustainable Drainage Guidance and Tool. The Greenfield runoff estimation for sites tool. http://geoservergisweb2.hrwallingford.co.uk/uksd/greenfieldrunoff.aspx.
[14] Institute of Hydrology (1983), *The Flood Studies Supplementary Report Number 14*.
[15] Institute of Hydrology (2004), *Flood Estimation for Small Catchments Report number 124*.

2.6.20 Field investigations have not yet been undertaken due to limited access to land and the need to integrate investigative requirements from several disciplines.

Sewer systems flood risk

2.6.21 The risk of flooding from the sewer network has also been addressed in this FRA. The sewer network data was provided for this assessment by the relevant water company, Severn Trent Water, to determine locations of the route and other design elements which will be located at areas of risk.

Other sources of flood risk

2.6.22 Reservoir flood risk was assessed using the reservoir inundation maps as shown on Volume 5: Map Book, Maps WR-01-037 and 038. The purpose was to identify areas along the route that were at risk of flooding if any reservoirs in the vicinity were to fail.

2.6.23 Canals have been identified as another source of potential flood risk, and so canals that will be crossed by certain sections of the route have been identified in the assessment.

3 Design criteria

3.1 Principal design criteria

3.1.1 The Proposed Scheme will provide a safe and reliable high speed rail link which will be compatible with the existing rail network and also HS1.

3.1.2 The Proposed Scheme will provide a 'passenger' only service and not 'freight' operation.

3.1.3 The design shall seek to ensure that any impacts as a result of its development will be designed out or minimised as far as practicably possible.

3.2 Flood risk design approach statement

3.2.1 The overall project seeks to ensure that there will be no increase in flood risk to any existing receptors as a result of the Proposed Scheme. This will be achieved by ensuring that overall flood storage capacity is maintained including an allowance for climate change.

3.2.2 In line with the NPPF technical guidance, increases in peak rainfall intensity and peak river flow of 20%, as a result of climate change, have been allowed for as per the period 2085 to 2115. This 20% increase has been used for the purposes of assessing flood risk. However, the hydraulic modelling involves sensitivity testing which includes a 20% increase, in addition to the 20% allowance for climate change.

3.2.3 All underbridge and viaduct crossings will be designed to allow the 1 in 100 (1%) annual probability flow (with allowance for climate change) to pass underneath. Upstream water levels will not be increased and a minimum of 600mm freeboard will be provided to the bridge soffits above this level which will allow for debris should flooding occur. On main rivers, where possible, a freeboard of 1m has been allowed.

3.2.4 Main river underbridges and viaducts will also accommodate river maintenance requirements and allow for a 5.3m vertical clearance above the floodplain ground level.

3.2.5 Culverts have been designed to convey the 1 in 100 (1%) annual probability flow (with allowance for climate change), with a freeboard of 300mm as a minimum applied for the culvert design. The design has also taken into account submerged inverts and the inclusion of mammal ledges.

3.2.6 River crossings will minimise any requirement for replacement floodplain storage areas.

3.2.7 The proposed rail infrastructure will be protected against inundation in the 1 in 1000 (0.1%) annual probability flood event. This will be achieved through ensuring a freeboard of 1m on the 1 in 1000 (0.1%) annual probability flood level. The railway drainage will be designed to have capacity up to the 1 in 100 (1%) annual probability peak rainfall event. However, the design will also ensure that the flood level does not exceed 1m below the track level during the 1 in 1000 (0.1%) annual probability rainfall event.

3.2.8 All drainage will be attenuated in order that peak surface water run-off from the proposed infrastructure is no greater than the existing current day baseline run-off under the 1 in 100 (1%) annual probability peak rainfall event.

3.2.9 All drainage will be designed to ensure that disruption to existing groundwater flood flows will be kept to a minimum, both during and following construction of the permanent works.

3.3 Cross drainage design approach statement

3.3.1 The drainage design will ensure that there is no increase in run-off to the receiving watercourse as a result of the Proposed Scheme.

3.3.2 Surface and ground water drainage shall be provided so as to ensure that water levels do not rise above a 1m freeboard below the rail level.

3.3.3 The route will be designed to ensure safe operation of trains during a 1 in 1000 (0.1%) annual probability event.

3.3.4 As part of the drainage design an allowance of 30% has been added to design events for climate change.

4 Data sources

4.1.1 Consistent with the requirements of the NPPF, this assessment considers the risk of flooding from rivers, overland flow (surface water), rising groundwater, overwhelmed drainage and sewer systems, and artificial sources such as reservoirs, lakes and canals.

4.1.2 The route will lie entirely outside the extent of flooding from the sea and therefore the risk of flooding from tidal sources is not considered in this assessment.

4.1.3 The primary datasets for each source of flooding used to assess the design elements are:

- OS 1:10,000 mapping;
- topographic survey commissioned for the purposes for the Proposed Scheme (200mm grid resolution LiDAR survey, in DTM and digital surface model format);
- Environment Agency Flood Zone mapping and historic flood mapping;
- Environment Agency website for reservoir inundation mapping;
- Lichfield SFRA[9];
- Staffordshire PFRA[10]
- Environment Agency national surface water flood mapping datasets specifically the Midlands FMfSW; and
- Severn Trent Water asset mapping.

4.1.4 A high-level review of the risk of flooding and potential impacts is undertaken on the basis of these datasets across all flood sources. Where this review indicates potentially significant impacts on the risk of flooding, or a risk of flooding to the line, further investigation is undertaken, specifically hydraulic modelling for the areas at risk from river flooding.

5 The Proposed Scheme

5.1 Permanent works

5.1.1 The general design of the Proposed Scheme is described in Volume 1. The following section describes the main features of the Proposed Scheme in this study area, including the main flood risk mitigation measures.

Overview

5.1.2 The route initially crosses Whittington Heath Golf Club proceeding in a northerly direction. It then passes over Lichfield Road and then under Darnford Lane just to the east of Whittington Hill Farm. With Lichfield to the west, the route curves to the west passing over a minor watercourse, an under-restoration canal, Cappers Lane, then over Broad Lane, and the West Coast Mainline. The route then continues to the east of Streethay, passing over the South Staffordshire Railway Line and the A38.

5.1.3 The line passes to the west of the Fradley Business Park, crossing over Wood End Lane, whereupon the route curves tighter towards the west, crossing over the Trent and Mersey Canal twice, Curborough Brook (via the Pyford Brook viaduct), and through Ravenshaw Wood. As the route crosses over Kings Bromley footpath 0.392 it curves back toward the north, crossing over the existing A515 Lichfield Road, Bourne Brook and the WCML. The Proposed Scheme will connect with the WCML to the south of Handsacre.

Whittington Heath Golf Club open section

5.1.4 The approximate length of this section will be 1.8km. The Proposed Scheme enters this area in a cutting at Whittington Heath Golf Club. For the full length of this section the Proposed Scheme will be in cutting or on embankment.

5.1.5 As the Proposed Scheme enters this section the depth of the cutting will be approximately 8.5m and will gradually rise to ground level before and after the Whittington footpath 16 underpass. Key features of this section include (see Volume 2: CFA22, maps CT-06-123 to CT-06-124):

- continuation of cutting from the adjoining area (CFA21) for approximately 330m from where it crosses the A51 Tamworth Road and reaches a maximum depth of 7m;
- an embankment for approximately 830m reaching a maximum height of approximately 10m at the Lichfield Road underpass. Landscape mitigation earthworks with false cuttings and landscape planting will be provided on both sides of the railway to the north of Lichfield Road;
- a cutting for approximately 350m to a maximum depth of approximately 3m. Landscape mitigation earthworks with false cuttings will be provided on both sides of the railway;
- an embankment approximately 375m long (see Volume 2: CFA22, map CT-06-124, D6 to F6) up to Cappers Lane viaduct, with a maximum height of approximately 14.7m. Landscape mitigation earthworks with false cuttings and landscape planting will be provided on both sides of the railway; and

- a drainage pond will be provided on the east side of the route just south of Mill Farm.

Cappers Lane viaduct, Fulfen Wood viaduct and Streethay viaduct

5.1.6 The approximate length of this section will be 1.6km. The Proposed Scheme will continue north predominantly on embankment, up to 16m in height.

- Key features of this section include (see Volume 2: CFA22, maps CT-06-124 to CT-06-125):
- a viaduct over Cappers Lane and the under restoration Wyrley and Essington canal, approximately 250m long; embankment approximately 350m long (see Volume 2: CFA22, map CT-06-124, C5 to CT-06-124, A5) from Cappers Lane viaduct with a maximum height of over 13m;
- Fulfen Wood viaduct crossing over the WCML (see Volume 2: CFA22, map CT-06-125, G5);
- an embankment approximately 900m long (see Volume 2: CFA22, map CT-06-125, H5 to D6) and with a maximum height of approximately 16m; and
- a viaduct approximately 300m long over the South Staffordshire Railway Line and the A38 (see Volume 2: CFA22, map CT-06-125, C6).

5.1.7 In addition, as shown in Volume 2: CFA22, maps CT-06-124 and CT-06-125, a drainage pond will be provided to the west of the route north of Cappers Lane (see Volume 2: CFA22, map CT-06-124, B7 to C7). A balancing pond to the west of the route north of the WCML (see Volume 2: CFA22, map CT-06-125, G6).

Trent and Mersey Canal east and west viaducts

5.1.8 The approximate length of this section will be 3.8km. The Proposed Scheme continues north predominantly on embankment, up to 14m in height.

5.1.9 Key features of this section include (see Volume 2: CFA22, maps CT-06-125 to CT-06-128):

- an embankment of approximately 450m (see Volume 2: CFA22, map CT-06-125, D6; to CT-06-126, H5) with a maximum height of approximately 14m, from the Streethay viaduct to a proposed culvert over Mare Brook (see Volume 2: CFA22, map CT-06-126, H3);
- an embankment of 1.5km (see Volume 2: CFA22, map CT-06-126, H3; to CT-06-127, H7) with a maximum height of 11m, from the proposed culvert over Mare Brook to Wood End Lane underbridge. The embankment will continue further for approximately 900m with a maximum height of 8m to form the stub of the Proposed Scheme for Phase Two to Manchester. This will be followed by a 100m-long bridge over the Trent and Mersey Canal to the east of the Phase One route (See Volume 2: CT-06-127, C4); The extent of the Phase One works will stop to the north of the Trent and Mersey Canal (see Volume 2: CFA22, map CT-06-12, B4);
- the two tracks to the WCML continue on an embankment approximately 400m

long and up to 17m high to the Trent and Mersey Canal;

- two crossings of the Trent and Mersey Canal occur either side of the crossing of the Curborough Brook. Separate structures take each track first over the Trent and Mersey Canal East viaducts (70m long) (see Volume 2: CFA22, Map CT-06-127, C6), then cross on a 80m viaduct over Curborough Brook (see Volume 2: CFA22, map CT-06-127, B6), then over the Trent and Mersey Canal West viaducts (130m long) (see Volume 2: CFA22, map CT-06-128, H5);
- embankments will be provided between this series of viaducts, reaching a maximum height of approximately 14m above the ground. Where the tracks are at different levels retaining walls will be provided between the tracks; and
- a drainage pond will be provided to the east of the route (see Volume 2: CFA22, map CT-06-126, G3). Two other drainage ponds will be provided to the north of the realigned Wood End Lane (see Volume 2: CFA22, map CT-06-127, G7 and G8), with another to the south of the realigned Wood End Lane (see Volume 2: CFA22, map CT-06-127, H7). A drainage pond will be located adjacent to the south-east of the Trent and Mersey Canal (see Volume 2: CFA22, map CT-06-127, D6) and there will be a further two drainage ponds to the west of the canal, each side of the Curborough Brook (see Volume 2: CFA22, map CT-06-127, B6 to B7 and C6). Another drainage pond will be located to the south of the Trent and Mersey Canal West viaduct (see Volume 2: CFA22, map CT-06-128, H5), with one more located south of the route to the north-east of Black Slough Farm (see Volume 2: CFA22, map CT-06-128, D6).

A515 Lichfield Road underbridge and Harvey's Rough flyover

5.1.10 The approximate length of this section is 4.3km. From the Trent and Mersey Canal West viaducts, the Proposed Scheme continues west on embankment, up to 13.2m in height, to the tie-in with the WCML.

5.1.11 The Proposed Scheme concludes in this section on embankment along the WCML tie-in and at-grade into Handsacre. Key features of this section include:

- an embankment of 1.9km (see Volume 2: CFA22, map CT-06-128, H5; to map CT-06-128, C6), varying in height from approximately 3m to approximately 12m at its northern end. Landscape planting will be provided on both sides of the route;
- a viaduct approximately 125m long over Bourne Brook (see Volume 2: CFA22, map CT-06-129, F7 to G7);
- an embankment approximately 550m long and approximately 13m high with a retaining wall on the south side as it approaches the diverted WCML tracks;
- an embankment, approximately 500m long with retaining walls along parts of the east side before the tracks connect to the inner WCML tracks;
- extension to the existing WCML embankments over approximately 2km from Bourne Brook to Handsacre and the diversion of the two easternmost of the four existing tracks;

- a balancing pond will be provided to the west of the A515 crossing (see Volume 2: CFA22, map CT-06-129, F6);
- a balancing pond will be located to the south of Handsacre (see Volume 2: CFA22, map CT-06-130a, E6 and E7).

5.2 Temporary works

5.2.1 All contractors will be required to comply with the environmental management regime for the Proposed Scheme, which will include:

- Code of Construction Practice (CoCP); and
- Local Environmental Management Plans (LEMP).

5.2.2 The key requirements of the draft CoCP in relation to flood risk are:

- making appropriate use of the Environment Agency's flood warning service;
- preparing site specific flood risk management plans for temporary works at risk of flooding from river, surface water and groundwater sources;
- considering flood risk when planning temporary sites and storing materials;
- obtaining consent, as required, for works affecting a watercourse;
- removing or stopping and sealing of drains and sewers taken out of use;
- not discharging of site run-off to ditches, watercourses, drains or soakaways without agreement of the appropriate authority;
- ensuring hoarding and fencing in areas at risk of flooding will be permeable to floodwater, unless otherwise agreed with the Environment Agency or Lichfield County Council (the Local Lead Flood Authority in this study area); and
- implementing precautions to be taken to prevent damage to services and to avoid pollution during service diversions, excavations and ground penetration.

5.2.3 The temporary works will include both main and satellite construction compounds. These compounds will be utilised for office accommodation, local storage for plant and materials, car parking, material processing facilities and welfare facilities.

5.2.4 Areas adjacent to these compounds may be used for temporary storage of topsoil stripped as part of the works.

5.2.5 Temporary worker accommodation will also be required for the Proposed Scheme.

6 Existing flood risk

6.1.1 Through the use of the Environment Agency historical flood maps, there are no areas of historical flooding that will be either crossed by the route or will be within 1km of the route.

6.1.2 The Lichfield SFRA[9] historical flood maps indicate there is one recorded incident of flooding in the vicinity of the route. The event caused inundation 150m west of the route at Streethay. The source of this flooding is unknown. Apart from the above recorded incident, there are no further areas of historical flooding which either cross the route or are within 1km of the route centreline. This includes flood events from rivers, surface water, artificial sources, canals or unknown sources.

6.1.3 The Staffordshire PFRA[10] has also been used to identify potential locations of flooding in the vicinity of the route. This mapping indicates that historical events have occurred in the vicinity of the proposed Cappers Lane viaduct crossing. These events have been classed as exceptional, however not affecting any properties.

6.2 River flooding

6.2.1 River flood risk is the risk of flooding posed by rivers and streams. The risk in CFA22 is from Mare Brook, Curborough Brook, Bourne Brook and associated tributaries. Flood maps indicating the areas at risk from river flooding are shown in Volume 5: Map Book – Water resources, Maps WR-05 and WR-06.

6.2.2 The assessment of baseline (current) flood risk involved identifying watercourse crossings and the associated risk through the use of the Environment Agency Flood Zones. The results of this assessment are provided in Table 2. The watercourse identifier references have been taken from Volume 5: Map Book – Water resources Maps WR-01-037 and 038.

Table 2: Whittington to Handsacre river flood risk

Watercourse identifier and map reference	Crossing name	Watercourse	1 in 100 (1%) + climate change flow	Risk level	Receptor vulnerability
SWC-CFA22-001 Volume 5: Map WR-01-037, E5.	Cappers Lane viaduct	Ordinary Watercourse(tributary of Fisherwick Brook)	1.22m^3/s	Very high	More vulnerable
SWC-CFA22-003 Volume 5: Map WR-01-037, E5.	Fulfen Wood culvert	Main river (Mare Brook)	3.12m^3/s	Very high	Less vulnerable
SWC-CFA22-004 Volume 5: Map WR-01-037, C6.	Mare Brook south culvert	Ordinary Watercourse (tributary of Mare Brook)	0.47m^3/s	Very high	Less vulnerable
SWC-CFA22-006 Volume 5: Map WR-01-037, B6.	Mare Brook north culvert	Ordinary watercourse (tributary of Mare Brook)	0.44m^3/s	Very high	Less vulnerable

Watercourse identifier and map reference	Crossing name	Watercourse	1 in 100 (1%) + climate change flow	Risk level	Receptor vulnerability
SWC-CFA22-007 Volume 5: Map WR-01-037, B6.	Curborough embankment	Ordinary watercourse is sourced in close proximity to the Proposed Scheme	Not calculated	Low	Less vulnerable
SWC-CFA22-010 Volume 5: CFA22 Map Book, Map WR-01-038, G5.	Pyford Brook viaducts	Main river (Curborough Brook)	8.46m^3/s	Very high	Less vulnerable
SWC-CFA22-012 Volume 5: Map WR-01-038, E7.	Bourne Brook viaduct	Ordinary Watercourse (Bourne Brook)	12.73m^3/s	Very high	Less vulnerable
SWC-CFA22-015 Volume 5: Map WR-01-038, D8.	Harvey's Rough flyover	Ordinary watercourse is sourced in close proximity to the Proposed Scheme	Not calculated	Low	Less vulnerable
SWC-CFA22-017 Volume 5: Map WR-01-038, C8.	Handsacre east culvert	Ordinary watercourse (tributary of River Trent)	0.12m^3/s	Very high	Less vulnerable
SWC-CFA22-018 Volume 5: Map WR-01-038, C8.	Handsacre west culvert extension	Ordinary watercourse (tributary of River Trent)	0.27m^3/s	Very high	More vulnerable

6.2.3 The Environment Agency Flood Zone mapping indicates four main areas at risk from flooding:

- the southern extent of the study area at the location of the Cappers Lane viaduct (Volume 5: Map WR-01-037, E5);
- at the location of the Fulfen Wood culvert (Volume 5: Map WR-01-037, E5);
- at the location of the Pyford Brook viaducts (Volume 5: Map WR-01-038, G5);
- to the northern extent of the study area at the location of the Bourne Brook viaduct (Volume 5: Map WR-01-038, E7).

6.2.4 These crossing locations fall within Flood Zone 3. However, given that the route will cross the watercourse, they will also be located within Flood Zone 3b (very high risk).

6.2.5 The Environment Agency flood mapping covers watercourses with catchments greater than 0.5km^2, and hence small catchments are often not represented. This includes the two tributaries of Mare Brook (Volume 5: Map WR-01-037, C6, SWC-CFA22-004; Volume 5: Map WR-01-037, B6, SWC-CFA22-006), and the two tributaries of the River Trent (Volume 5: Map WR-01-038, C8, SWC-CFA22-017; Volume 5: Map WR-01-038, C8, SWC-CFA22-018).

6.2.6 Hydraulic modelling was carried out to provide a more accurate representation of river flood risk along the route, specifically at locations where the route will cross a watercourse. The modelling provided flood extents for the 1 in 100 (1%) annual

probability event with a 20% allowance for climate change and for the 1 in 20 (5%) annual probability event. Flood levels were also determined for the 1 in 1000 (0.1%) annual probability event to ensure that the proposed track will not be at risk during this event. The flood extents and levels as determined through hydraulic modelling are detailed in the river modelling report (Volume 5: WR-004-015).

6.2.7 The Environment Agency flood mapping indicates that the Mare Brook South culvert, the Mare Brook north culvert, the Handsacre east culvert and the Handsacre west culvert extension are all located within Flood Zone 1. However, following hydraulic modelling completed for this assessment they are all redefined as Flood Zone 3b. Therefore, the risk classification given at these locations are very high.

6.2.8 The two ordinary watercourses located south of Gorse Farm (Volume 5: Map WR-01-037, B6, SWC-CFA22-007) and south of Bromley Hayes (Volume 5: Map WR-01-038, D8, SWC-CFA22-015) have not been hydraulically modelled. These watercourses start and flow away from the route, therefore the route will not cross the watercourse. Any overland flow that will pass into this watercourse will be intercepted by the proposed drainage system.

6.2.9 The vulnerability classification as shown in Table 2 above has been taken from the NPPF and relates to the vulnerability of existing development in areas currently at risk from river flooding. 200m downstream of the Cappers Lane viaduct are two properties that are within or adjacent to the 1 in 1000 (0.1%) annual probability flood extent and hence would be at an increased risk as a result of higher flood levels. These properties are both residential and hence are considered more vulnerable in line with NPPF. Immediately upstream of the Handsacre West culvert extension crossing there are numerous residential properties adjacent to the watercourse. Given their close proximity, this location has been considered as more vulnerable. At the other crossings, a less vulnerable classification has been assigned because the land use is agricultural.

6.2.10 The other locations along the route not identified in Table 2 are considered to be at either a low risk or no risk of river flooding.

6.3 Surface water/overland flow

6.3.1 This section is an examination of the existing flood risk posed by rainfall falling on the ground surface, referred to as surface water flooding. It is examined in terms of the water flowing over the ground surface that has not entered a natural drainage channel or artificial drainage system.

6.3.2 The areas at risk from surface water flooding are shown on map Volume 5: Maps WR-01-037 and 38. Table 3 details the risk to the development from this source of flooding.

Table 3: Whittington to Handsacre sources of surface water flooding

Description of surface water flooding location and map reference	Description of possible influence to the Proposed Scheme	Risk
Whittington Heath Volume 5: Map WR-01-037, G6 and G7.	The route will run parallel to an area at risk from surface water flooding 100m from the route. This area is considered a low, medium and high risk. There are also isolated areas at risk from surface water flooding to the east of the route, at a low and medium risk associated with ponds.	High
North west of Whittington in the vicinity of the Wyrley and Essington Canal Volume 5: Map WR-01-037, E6.	Two areas at risk from surface water flooding will be crossed by the route. These areas are associated with watercourses and area at a low, medium and high risk.	High
North east of Streethay, west of the Coventry Canal Volume 5: Map WR-01-037, D5, C5 and C6.	Two areas at risk from surface water flooding will be crossed by the route. One area is associated with a watercourse and is at a low, medium and high risk, the other is not associated with a watercourse and is at a low and medium risk. There are also small isolated areas at risk surrounding the route, associated with ponds, at a low, medium and high risk.	High
South west of Fradley South Volume 5: Map WR-01-038, H5.	The route will be located on an area at risk from surface water flooding associated with a watercourse, at a low, medium and high risk	High
West of Fradley South Volume 5: Map WR-01-038, G5.	There are isolated areas at risk from surface water flooding both east and west of the route, not associated with a watercourse, at a low and medium risk. An area at risk of surface water flooding will also be crossed by the route, associated with a watercourse, at a low, medium and high risk.	High
To the north of wood end farm and Vicar's Coppice Volume 5: Map WR-01-038, E7 and F6.	Numerous isolated areas susceptible to surface water flooding, not associated with a watercourse, will be crossed by the route and are located parallel to the north and south of the route. These areas are at a low, medium and high risk.	High
From the west of the A515 to John's Gorse Volume 5: Map WR-01-038, E7.	An area at risk from surface water flooding, associated with a watercourse, will be crossed by the route, at a low, medium and high risk.	High
Harvey's Rough to Handsacre Volume 5: Map WR-01-038, D5 and C5.	An area at risk runs parallel to the south of the route and also will be crossed by the route, associated with a watercourse, at a low, medium and high risk.	High

6.3.3 There are eight locations along the route in this study area which have been identified to be at risk from surface water flooding from the Environment Agency FMfSW. At the majority of these locations the risk of surface water flooding ranges from low to high. However, as a conservative approach the highest level of risk has been assigned. Therefore, at all locations the risk is considered high.

6.3.4 In line with the risk category matrix provided in Table 1, and the data available for this FRA, all other locations along the route within this study area are classed to be at no risk from surface water flooding.

6.4 Groundwater

6.4.1 Groundwater flood risk has been qualitatively assessed based on hazard identification and evaluation using the conceptual understanding of the ground conditions at the location of the Proposed Scheme. The assessment of the current groundwater flood risk is based on the presence or otherwise of an aquifer and the relative depth of groundwater level, as well as historical information on the occurrence of groundwater flooding incidents.

6.4.2 The solid geology is predominantly classified as a Secondary B aquifer. Superficial Deposits are classified as Secondary A aquifers, Secondary B aquifers and Unproductive Strata.

6.4.3 Only very limited data on groundwater levels has been made available within the study area. However, it is considered that groundwater flow is likely to be towards watercourses and groundwater, especially within the alluvium may be within 2m of ground level.

6.4.4 The SFRA[9] and PFRA[10] do not record any instances of groundwater flooding and therefore the risk is assessed as low.

6.5 Sewer systems

6.5.1 Sewer infrastructure is a potential source of flood risk in the event of a failure. Due to the nature of the closed sewer system, sewer flooding will only be caused if there is a blockage or a leak or if there is a rainfall event greater than the design capacity of the network

6.5.2 The risk to the route from the sewer network has been determined based on the location of development in relation to the network and the proximity and potential flow paths from inspection covers. Flow paths have been assessed through the use of LiDAR and OS mapping.

6.5.3 Three locations have been identified to be a potential risk from the sewer network, being located south of Fradley Park, north of Ravenshaw Wood, and east of Handsacre (Volume 5: Map WR-01-038, H5, F6 and C8). At these locations the route will cross and/or there are inspection covers located within the vicinity of the route. However the topography indicates at these locations there are no flow paths to the Proposed Scheme. Therefore the risk from the sewer network at these locations is low.

6.5.4 Three further locations have been identified, all located east of Whittington Barracks (Volume 5: Map WR-01-037, H5 and I5). At these locations the route will be located approximately 30m from three inspection covers, and the topography indicates there are restricted pathways to the route due to the topography and proposed design. If surcharging occurs at these locations, flood water either side of the route would flow along the drainage channels and into the associated watercourse (SWC-CFA22-006). Therefore the risk from the sewer network at these locations is medium.

6.6 Artificial sources

6.6.1 Artificial sources of flood risk describe a mechanism whereby flooding would be the result of failure of infrastructure that impounds water such as in a canal or reservoir.

6.6.2 The Wyrley and Essington Canal (Volume 5: Map WR-01-037, E5, SWC-CFA22-002) will be crossed by the proposed Cappers Lane viaduct. Through the use of LiDAR data it is considered that the Wyrley and Essington Canal, at the location of the crossing, is raised above surrounding ground level and hence there is a risk of structural breaching when the water level is maintained at the design level. If breaching occurs however, flood water would flow along the corridor of the watercourse at this location (Volume 5: Map WR-01-037, E5, SWC-CFA22-001) and so not adversely affect the route. If overtopping occurs, flood water would flow along the same route as the drain near this location (Volume 5: Map WR-01-037, E5, SWC-CFA22-001).

6.6.3 The Trent and Mersey Canal (Volume 5: CFA22 Map Book, Map WR-01-038, G5, SWC-CFA22-010) will be crossed twice by the Proposed Scheme, at the Trent and Mersey Canal East viaducts and Trent and Mersey Canal West viaducts. Through the use of LiDAR data it is considered that the Trent and Mersey Canal, at the two locations crossing the route, are not raised above surrounding ground level and hence there is no risk of structural breaching when the water level is maintained at the design level. If overtopping occurs at either of these locations, flood water would flow into the proposed drainage system along the toe of the viaduct embankments and discharge to the Curborough Brook (Volume 5: CFA22 Map Book, Map WR-01-038, G5, SWC-CFA22-010).

6.6.4 Water levels within canals are maintained and therefore it is unlikely that overtopping would occur. In line with the risk category matrix in Table 1 the risk of flooding from this source is considered low.

6.6.5 The Environment Agency reservoir inundation mapping identifies that the area surrounding the Cappers Lane viaduct crossing is at risk of flooding following reservoir failure. This area is at risk if Swinfen Lake was to fail. However, Swinfen Lake is over 3km upstream of the Proposed Scheme with roads in between the reservoir and the route which will act as constrictions to the flow and reduce velocities. Due to the low velocities of the flood water it is considered that flooding would be a low hazard at the location of the route. At this location, the inundation extent covers a greater extent than the Flood Zone mapping.

6.6.6 The reservoir inundation mapping also shows that the area surrounding the Pyford Brook viaducts crossing is at risk of flooding following reservoir failure. This area is at risk if Stowe Pool or Minster Pool were to fail. However, both reservoirs are over 3km upstream of the Proposed Scheme with roads in between the reservoir and the route which will act as constrictions to the flow and reduce velocities. Due to the low velocities of the flood water it is considered that flooding would be a low hazard at the location of the route. At this location, the inundation extent covers a greater extent than the Flood Zone mapping.

6.6.7 Due to the strict regulations and high maintenance associated with reservoirs, breaching is considered unlikely. In line with the risk category matrix in Table 1 the risk of flooding from this source is considered low.

6.7 Summary

6.7.1 The Proposed Scheme will cross eight watercourses and therefore it is concluded that the Proposed Scheme will be within areas that are classified as being potentially at a very high risk from river flooding in this study area. There are two areas in the study area where the land use has been categorised as more vulnerable, they are downstream of the Cappers Lane viaduct crossing, and immediately upstream of the Handsacre West culvert extension. All other land uses at risk in this study area (which could be impacted as a result of the Proposed Scheme) are classed as less vulnerable.

6.7.2 There are eight locations along the route which have been identified to be at risk from surface water flooding. The risk at these locations generally ranges from low to high, although as a conservative approach the highest level of risk has been assigned. Therefore, all locations have been categorised as at a high risk.

6.7.3 The risk presented by groundwater flooding is considered to be low.

6.7.4 At three locations the Proposed Scheme will cross the sewer network and an inspection cover is located within 120m of the route although there are no known flow paths to the route. At three further locations the sewer network crosses the route and there are inspection covers located on the route. At these locations there are restricted flow paths to the Proposed Scheme. Therefore, the route is at a medium risk of flooding from water and sewer networks.

6.7.5 Water levels within canals are continually maintained and hence the chance of overtopping or breaching when were levels raise above the design level and thus flood risk from this source is considered low. Similarly due to the strict monitoring and maintenance requirements, the risk of reservoir flooding to the Proposed Scheme is considered low.

7 Flood risk management measures

7.1 River flood risk

Flood risk to proposed scheme

7.1.1 The Proposed Scheme will be raised above the 1 in 1000 (0.1%) annual probability flood level at floodplain crossings. Therefore, the mitigation measures included in the design have ensured that there are no instances where the Proposed Scheme would be at significant risk of river flooding, and consequently no specific mitigation is required.

Impact of proposed scheme

7.1.2 At all floodplain crossings, replacement floodplain storage would be provided upstream of the Proposed Scheme for losses in floodplain storage, including viaduct piers, embankments and all associated development.

Fulfen Wood culvert

7.1.3 Hydraulic modelling at this location suggests that the Proposed Scheme will result in an afflux of up to 39mm, extending to a maximum distance of 162m upstream of the Fulfen Wood culvert during the 1 in 100 (1%) annual probability event with an allowance for climate change. This change in flood level causes a minor impact which will be reduced through the incorporation of replacement floodplain storage.

Other watercourse crossings

7.1.4 The hydraulic modelling for the other seven watercourse crossings in this study has shown that the Proposed Scheme will have a negligible impact on river flood risk. Areas of land have been identified as suitable to provide replacement floodplain storage, therefore reducing the impact. Any replacement floodplain storage at the locations of negligible impact is likely to provide betterment.

Mitigation for temporary works

7.1.5 The temporary works have the potential to result in an increased river flood risk and be at risk of flooding from this source. The proposed mitigation and measures to prevent an unacceptable risk of river flooding for the temporary works includes signing up to the Environment Agency flood warning system for the "Lower Tame – Low-lying land and roads between Hopwas and the National Arboretum near Alrewas" and the "Burton Trent – Low-lying land and roads between Kings Bromley to Clay Mills". Any temporary crossings will be designed to prevent an increased flood risk through ensuring sufficient capacity during the 1 in 100 (1%) annual probability event; an indication of the flows which will be considered are included in Table 2.

7.2 Surface water flood risk

Flood risk to Proposed Scheme

7.2.1 In this study area, areas categorised as being at a high risk of surface water flooding are generally associated with the watercourses identified in the river flooding sections in this report. At these locations the scheme design will ensure that the track is situated above the 1 in 1000 (0.1%) annual probability event flood level with a 1m

freeboard. Therefore as long as there is no blockage of these structures, a low surface water flood risk to the track is anticipated at these locations.

7.2.2 At the three locations where the route potentially crosses surface water flow paths, the track will either be raised on an embankment and/or the track drainage system will direct surface water flow away from the Proposed Scheme. Therefore, as long as the collection systems and surface water culverts are designed with sufficient capacity, there should be no backing up, and no expected risk of flooding to the Proposed Scheme.

Impact of Proposed Scheme

7.2.3 Potential increases in peak discharge rates of surface water run-off will be attenuated prior to discharging to the receiving watercourse. Any additional surface water to be discharged will be at a trickle rate to prevent exceeding the current capacity of the receiving watercourse.

7.3 Risk of flooding from groundwater

Flood risk to Proposed Scheme

7.3.1 The risk from groundwater flooding to the Proposed Scheme has been assessed as low and, therefore, no specific management measures are considered necessary.

Impact of the Proposed Scheme

7.3.2 The Proposed Scheme is no anticipated to have an impact on groundwater flooding and, therefore, no specific management is considered necessary.

7.4 Risk of flooding from sewer systems

7.4.1 There will be a medium risk of flooding from sewer systems to the Proposed Scheme, and there are no anticipated effects on the risks of flooding from drainage systems within the study area arising from the Proposed Scheme. Therefore, no specific mitigation would be required.

7.5 Risk of flooding from artificial sources

Flood risk to Proposed Scheme

7.5.1 There are no instances where the Proposed Scheme would be at significant risk of flooding from artificial sources, and consequently no specific mitigation is required.

Impact of the Proposed Scheme

7.5.2 The Proposed Scheme in this study area is at risk of flooding resulting from the complete failure of three reservoirs. However, the replacement floodplain storage provided to mitigate the potential effects of river flooding would serve to either fully or partially offset any potential effects of the Proposed Scheme on flooding from this source. Due to the low probability of such flooding occurring, and the likely low significance of any impacts arising from the Proposed Scheme, it is not considered appropriate to provide additional mitigation for this scenario.

8 Post development flood risk assessment

8.1 River flooding

8.1.1 The key design elements of the Proposed Scheme with potential flood risk considerations have been modelled for this FRA. The modelling methodology and results specific for each watercourse crossing are included in the river modelling report (Volume 5: WR-004-015) which is presented in the annex to this FRA. A summary of the results are presented in Table 4. The watercourse identifier references have been taken from Volume 5: Map Book – Water resources Maps WR-01-037 and 038.

Table 4: Whittington to Handsacre river flood risk

Watercourse identifier and map reference	**Crossing name**	**1 in 100 (1%)+ climate change flow**	**Change in flood level 1 in 100 (1%) +climate change**	**Change in flood level 1 in 1000 (0.1%)**	**Proposed Scheme 1 in 1000 (0.1%) level**	**Length of impacted upstream reach[16]**
SWC-CFA22-001 Volume 5: Map WR-05-062, G5	Cappers Lane viaduct	1.22m^3/s	0mm	3mm	63.207m AOD	0m
SWC-CFA22-003 Volume 5: Map WR-05-062, E6	Fulfen Wood culvert	3.12m^3/s	39mm	82mm	63.978m AOD	162m
SWC-CFA22-004 Volume 5: Map WR-05-063, I5	Mare Brook South culvert	0.47m^3/s	-6mm	15mm	64.212m AOD	0m
SWC-CFA22-006 Volume 5: Map WR-05-063, G5	Mare Brook North culvert	0.44m^3/s	-73mm	-92mm	64.488m AOD	0m
SWC-CFA22-007 Volume 5: Map WR-01-037, B6.	Curborough embankment	Not modelled because the Proposed Scheme does not cross a watercourse at this location.				
SWC-CFA22-010 Volume 5Map WR-05-063, B7	Pyford Brook viaducts	8.46m^3/s	0mm	8mm	64.210m AOD	0m
SWC-CFA22-012 Volume 5: Map WR-05-064, D7	Bourne Brook viaduct	12.73m^3/s	-9mm	7mm	73.833m AOD	0m
SWC-CFA22-015 Volume 5: Map WR-01-038, D8.	Harvey's Rough flyover	Not modelled because the Proposed Scheme does not cross a watercourse at this location.				

[16] Length of reach upstream of the Proposed Scheme along which flood levels during the 1 in 100 (1%) annual probability+ climate change are greater than 10mm.

Watercourse identifier and map reference	Crossing name	1 in 100 (1%)+ climate change flow	Change in flood level 1 in 100 (1%) +climate change	Change in flood level 1 in 1000 (0.1%)	Proposed Scheme 1 in 1000 (0.1%) level	Length of impacted upstream reach[16]
SWC-CFA22-017 Volume 5: Map WR-05-065, H6	Handsacre East culvert	0.12m^3/s	-42mm	-31mm	71.775m AOD	0m
SWC-CFA22-018 Volume 5Map WR-05-065, G6	Handsacre West culvert extension	0.27m^3/s	-77mm	-64mm	72.315m AOD	0m

8.1.2 The hydraulic modelling indicates that at seven of the eight crossing structures modelled, the Proposed Scheme will have a negligible impact on flood levels during the 1 in 100 (1%) annual probability with an allowance for climate change. Mare Brook South culvert causes a minor impact during the 1 in 1000 (0.1%) annual probability event. There are no increases in downstream peak flood levels as a result of the Proposed Scheme at all of these seven crossings.

8.1.3 The hydraulic modelling for Fulfen Wood culvert has indicated that the Proposed Scheme will result in a minor impact on flood levels during the 1 in 100 (1%) annual probability event with an allowance for climate change. However, modelling has shown that replacement floodplain storage can be provided upstream of this crossing to reduce change to a negligible impact. There are no increases in downstream peak flood levels as a result of the Proposed Scheme.

8.1.4 The results at the Pyford Brook viaduct crossing in Table 4 show that the Proposed Scheme will have a negligible impact on flood level. The model results reported here represents an early design iteration of the viaduct with a width of 95m which is different to the 63m width of the Proposed Scheme. Although these results do not reflect the proposed design at the Pyford Brook viaduct crossing, the flow during the 1 in 20 (5%) and the 1 in 100 (1%) with an allowance for climate change events remained in channel i.e. there was no flow across the floodplain and hence no impact from the viaduct embankments or piers. Therefore it was not necessary to reassess the impact of the narrower viaduct and hence the Proposed Scheme will have a negligible impact on flood risk at this location. The viaduct soffit will be in excess of 8m above the 1 in 1000 (0.1%) Proposed Scheme peak flood level, so the modelling also confirms the track will not be at risk of river flooding. Further details relating to the hydraulic modelling of the Pyford Brook viaduct is detailed in the river modelling report (Annex 5: WR-004-015).

8.1.5 Watercourses pose a river flood risk to the other design elements in this study area. The areas at risk from river flooding are shown on Volume 5: Map Book – Water resources, Maps WR-05-061 to 065 and are based on the hydraulic modelling results rather than Environment Agency Flood Zone mapping. The river flood risks to these works are included in Table 5.

Table 5: River flood risks to the other design elements

Works at risk	Watercourse identifier and map reference	Location description	Description of the works and flood risk	Risk
Highways Earthworks Landscaping	SWC-CFA22-004 Volume 5: Map WR-05-062, E6	Fulfen Wood culvert	Landscaping works and the earthworks for Fulfen Wood North Embankment will encroach into the areas as identified to be at risk during the 1 in 20 (5%) annual probability event. An access road will be located adjacent to the watercourse (SWC-CFA22-003) at this location.	Very high
Highways Earthworks Landscaping	SWC-CFA22-004 Volume 5: Map WR-05-063, I5	Mare Brook south culvert	Landscaping works and the earthworks for Streethay Embankment will encroach into the areas as identified to be at risk during the 1 in 20 (5%) annual probability event. An access road will be located adjacent to a tributary of Mare Brook at this location.	Very high
Highways Earthworks Landscaping	SWC-CFA22-006 Volume 5: Map WR-05-063, G5	Mare Brook north culvert	Landscaping works, an access road and the earthworks for Streethay Embankment will encroach into the areas as identified to be at risk during the 1 in 20 (5%) annual probability event. The access road includes two proposed culverts along the watercourse at this location. An access track will be located adjacent to the watercourse at this location.	Very high

8.1.6 The proposed access road from Cappers Lane, proposed access road from Streethay and the access track by Mare Brook North culvert will be located in areas at risk of river flooding however these roads and the track will not be embanked and hence it is considered to have an insignificant impact on river flood risk.

8.1.7 The proposed access road that crosses the ordinary watercourse (SWC-CFA22-006) just downstream from the Mare Brook North culvert crossing will be embanked. At this location two culverts are proposed, which have not been included in the hydraulic modelling. If these culverts are designed to convey the same flow as the Mare Brook North culvert upstream of these two proposed culverts, then there will not be a significant impact on flood risk.

8.1.8 In addition to the road culverts outlined in Table 5, there are further culverts proposed in this study area. However, these culverts are required for the surface water drainage system which forms part of the Proposed Works, rather than for existing watercourses. The capacity requirements for these culverts are addressed as part of the drainage design.

8.1.9 Temporary works as required for the construction phase are also located in areas at risk from river flooding. The temporary works at risk are listed in Table 6.

Table 6: River flood risk to temporary works

Watercourse identifier and map reference	Receptor	Comment	Risk
SWC-CFA22-001 Volume 5: Map WR-05-062, G5	Ordinary watercourse (tributary of Fisherwick Brook)	Cappers Lane viaduct (north) compound and temporary site access/haul route and fencing will be located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high

Watercourse identifier and map reference	Receptor	Comment	Risk
SWC-CFA22-003 Volume 5: Map WR-01-037, E5 and E6	Main river (Mare Brook)	Cappers Lane compound, a material transfer stockpile area and a temporary material compound will be located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high
SWC-CFA22-004 Volume 5Map WR-01-037, C5 and C6	Ordinary watercourse (tributary of Mare Brook)	A temporary bridge/culvert crossing, a temporary material stockpile and a temporary site access/haul route and fencing will be located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high
SWC-CFA22-006 Volume 5: Map WR-01-037, B6	Ordinary watercourse (tributary of Mare Brook)	Temporary site access/haul road and fencing, and temporary material stockpiles will be located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high
SWC-CFA22-010 Volume 5: Map WR-01-038, G5	Main River (Curborough Brook)	Temporary site access/haul road and fencing, and a temporary bridge/culvert will be located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high
SWC-CFA22-012 Volume 5: Map WR-01-038, E7 and E8	Main river (Bourne Brook)	Two temporary site access/haul roads and fencing, a temporary culvert/bridge, A515 Lichfield Road underbridge main compound, and a material transfer stockpile area are located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high
SWC-CFA22-017 Volume 5: Map WR-01-038, C8	Ordinary watercourse (tributary of River Trent)	Temporary site access/haul road and fencing, and a temporary earthworks stockpile area will be located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high
SWC-CFA22-018 Volume 5: Map WR-01-038, C8	Ordinary watercourse (tributary of River Trent)	Temporary site access/haul road and fencing, and a temporary earthworks stockpile area will be located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high

8.1.10 There are eight locations of temporary works that are located in areas at risk from river flooding. The areas at risk have been identified through the hydraulic modelling completed for this assessment.

8.1.11 Hydraulic modelling is not considered necessary for the temporary works because the works will be constructed in line with the CoCP and thus the design will consider river flood risk. Therefore temporary works will not result in an increased flood risk to any existing receptors.

8.1.12 The hoarding and fencing around a site for security purposes has the potential to alter flow paths and thus impact on flood risk at the three locations identified in Table 6. However, the CoCP states that hoarding and fencing in areas at risk of flooding will be permeable to floodwater, unless otherwise discussed with the Environment Agency or Local Lead Flood Authority. This will ensure that the floodplain continues to function effectively for storage and conveyance of floodwater.

8.1.13 The temporary works other than those outlined in Table 6 are considered to be at a low risk of river flooding.

8.2 Surface water/overland flow

8.2.1 The proposed track will result in increased run-off rates due to a reduction in infiltration capacity. Therefore, the entire length of the track may be at risk from this source and could increase risk elsewhere.

8.2.2 In addition the track drainage has the potential to increase flood risk in receiving watercourses if not attenuated. In this study area there are seventeen proposed balancing ponds, these are located as follows:

- either side of the Proposed Scheme at the Darnford Lane overbridge (Volume 2: CFA22, Map CT-06-124, F5 and F7);
- either side of Cappers Lane viaduct crossing (Volume 2: CFA22, Map CT-06-124, D6 and C7);
- adjacent to the Broad Lane underpass (Volume 2: CFA22, Map CT-06-125, I4);
- west of the Fulfen Wood culvert crossing (Volume 2: CFA22, Map CT-06-125, G6);
- north of the Mare Brook north culvert crossing (Volume 2: CFA22, Map CT-06-126, G3);
- three in the vicinity of the Wood End Lane underbridge (Volume 2: CFA22, Map CT-06-127, H6, G6 and G7);
- two in the vicinity of the Trent and Mersey east viaducts(Volume 2: CFA22, Map CT-06-127, D6 and C6);
- two in the vicinity of the Trent and Mersey west viaducts (Volume 2: CFA22, Map CT-06-128, J6 and H5);
- North-east of Black Slough Farm (Volume 2: CFA22, Map CT-06-128, D6);
- adjacent to the Bourne Brook viaduct crossing (Volume 2: CFA22, Map CT-06-129, F6); and
- south of the route at Handsacre west culvert extension crossing (Volume 2: CFA22 Map Book, Map CT-06-130a, E7).

8.2.3 The outfall from these balancing ponds will be attenuated to ensure that run-off rates are not increased above existing levels to prevent an increase in risk.

8.2.4 The route has the potential to interrupt surface water movement, which could result in an increase in surface water flood risk. The Environment Agency FMfSW indicates that the Proposed Scheme will interrupt three surface water flow paths in this study area.

8.2.5 To the north east of Streethay there is an overland flow path. However, surface water at this location flowing away from the Proposed Scheme will discharge into the tributary of Mare Brook (Volume 5: CFA22, Map WR-01-037, C5) and hence will flow as existing. Surface water flow paths towards the Proposed Scheme, at this location, will be collected prior to being discharged via a proposed balancing pond if necessary to the tributary of Mare Brook (SWC-CFA22-004). Although there will be an interruption

to surface water movement at this location; it is considered there will be no impact on surface water flood risk as a result of the Proposed Scheme at this location.

8.2.6 Between the north of Wood End Farm and Vicar's Coppice there are two overland flow paths. However, surface water at both these locations flowing away from the Proposed Scheme will discharge into the Trent and Mersey Canal and hence will flow as existing (Volume 5: CFA22, Map WR-01-038, E7 and F6). Surface water flow paths towards the Proposed Scheme, at these locations, will be collected prior to being discharged via a proposed balancing pond if necessary to the Trent and Mersey Canal. Although there will be an interruption to surface water movement at this location; it is considered there will be no impact on surface water flood risk as a result of the Proposed Scheme at this location.

8.2.7 The potential impact of the Proposed Scheme on surface water movement, not identified as above, will be incorporated within the scheme design. Therefore, the works will have no impact on surface water flood risk.

8.2.8 There are other design elements of the Proposed Scheme which will be at risk from surface water flooding. The surface flood risks to the other design elements, as identified from the Environment Agency FMfSW are included in Table 7.

Table 7: Surface water flood risks to other design elements of the Proposed Scheme

Works at risk	Location description and map reference	Description of possible influence to the Proposed Scheme	Risk
Highways	Access road from Marsh Lane, at the junction with Whittington Common Road Volume 5: Map WR-01-037, F6.	The proposed access road will be located in an area at a low risk of surface water flooding. This area is not associated with a watercourse.	Low
Highways Earthworks Landscaping	Fulfen Wood culvert Volume 5: Map WR-01-037, E5 and E6.	A balancing pond and associated access road, landscaping works and the earthworks for Fulfen Wood north embankment will be located in areas at low, medium and high risk of surface water flooding. This area is associated with a watercourse (SWC-CFA22-003).	High
Earthworks Landscaping	North-east of Streethay, west of the Coventry Canal Volume 5: Map WR-01-037, C5.	Landscaping works and the earthworks for Streethay embankment are located in an area at a low and medium risk of surface water flooding, not associated with a watercourse.	Medium
Highways Earthworks	Mare Brook south culvert Volume 5: Map WR-01-037, C5 and C6.	An access road and the earthworks for Streethay embankment are located in an area at a low, medium and high risk of surface water flooding, associated with a watercourse (SWC-CFA22-004).	High
Highways Earthworks Landscaping	East of Curborough House Volume 5: Map WR-01-037, A6 and B6.	Landscaping works, the earthworks for Streethay embankment and a realigned PRoW are located in areas at a low, medium and high risk of surface water flooding, associated with a watercourse (SWC-CFA22-006).	High
Earthworks	Pyford Brook viaducts Volume 5: Map WR-01-038, G5.	Earthworks for Pyford Brook east embankment and Pyford Brook west embankment are located in an area at a low, medium and high risk of surface water flooding, associated with a watercourse (SWC-CFA22-010).	High

Works at risk	Location description and map reference	Description of possible influence to the Proposed Scheme	Risk
Highways Earthworks	Ravenshaw Wood to Vicar's Coppice Volume 5: Map WR-01-038, F6 and E7.	Earthworks for Ravenshaw Wood embankment and a realigned footpath and bridleway are located in areas at a low and medium risk of surface water flooding, not associated with a watercourse.	Medium

8.2.9 There are seven locations where other design elements are located in areas susceptible to surface water flooding. In general these areas range from low to high risk and as a conservative approach the highest level of risk has been assigned. Therefore, four of the seven locations are categorised as being at a high risk, two being at a medium risk, and one at a low risk of surface water flooding.

8.2.10 The other design elements not listed in Table 7 are considered to be at no risk from surface water flooding in line with the flood risk category matrix.

8.2.11 All other design elements, including those additional to Table 7, have the potential to increase surface water run-off rates through reduced infiltration capacity. The design for the Proposed Scheme includes surface water run-off management (such as drainage channels and balancing ponds) to prevent an increased risk of flooding from this source both on site and in neighbouring areas.

8.2.12 Table 8 details the risk to the temporary design elements from surface water flooding.

Table 8: Sources of surface water flooding to temporary works

Description of surface water flooding location and map reference	Description of possible influence on temporary design elements	Risk
Marsh Lane at the junction with Whittington Common Road Volume 5 Map WR-01-037, F6	Temporary fencing will be located in an area at a low risk of surface water flooding, not associated with a watercourse.	Low
In the vicinity of the Cappers Lane viaduct crossing Volume 5: Map WR-01-037, E5 and E6	Cappers Lane viaduct (west) compound, Cappers Lane viaduct (north) compound and temporary site access/haul route and fencing will be located in areas at a low, medium and high risk of surface water flooding associated with a watercourse (SWC-CFA22-001).	High
In the vicinity of the Fulfen Wood culvert crossing Volume 5: Map WR-01-037, E5 and E6	Cappers Lane main compound, a material transfer stockpile area and a temporary material stockpile will be located in areas at a low, medium and high risk of surface water flooding associated with a watercourse (SWC-CFA22-003).	High
North east of Streethay, east of the Coventry Canal Volume 5: Map WR-01-037, C5	A temporary material stockpile is located in an area at a low and medium risk of surface water flooding, not associated with a watercourse.	Medium
In the vicinity of the Mare Brook south culvert crossing Volume 5: Map WR-01-037, C5 and C6	A temporary bridge/culvert crossing, a temporary material stockpile and a temporary site access/haul route and fencing will be located in an area at a low, medium and high risk of surface water flooding, associated with a watercourse (SWC-CFA22-004).	High

Description of surface water flooding location and map reference	Description of possible influence on temporary design elements	Risk
East of Curborough House Volume 5: Map WR-01-037, B6	Temporary site access/haul road and fencing, and temporary material stockpiles will be located in areas at a low, medium and high risk of surface water flooding, associated with a watercourse (SWC-CFA22-006).	High
South of Fradley Wood Volume 5: CFA22 Map Book, Map WR-01-037, A6	A temporary material stockpile will be located in an area at a low and medium risk of surface water flooding, not associated with a watercourse.	Medium
In the vicinity of the Pyford Brook viaducts crossing Volume 5: Map WR-01-038, G5 and G6	Temporary site access/haul road and fencing, and a temporary bridge/culvert will be located in areas at a low, medium and high risk of surface water flooding, associated with a watercourse (SWC-CFA22-010). Trent & Mersey Canal West viaducts (south-west) compound is located in an area at a low and medium risk of surface water flooding, not associated with the Trent and Mersey Canal.	High
Ravenshaw Wood to Vicar's Coppice Volume 5: CFA22 Map Book, Map WR-01-038, F6	Temporary site access/haul road and fencing, and a temporary earthworks stockpile will be located in areas at a low and medium risk of surface water flooding, not associated with a watercourse.	Medium
In the vicinity of the Bourne Brook viaduct crossing Volume 5: Map WR-01-038, E7 and E8	Two temporary site access/haul roads and fencing, a temporary culvert/bridge, A515 Lichfield Road underbridge compound and a material transfer stockpile area, are located in areas at a low and medium risk of surface water flooding. This area is associated with a watercourse (SWC-CFA22-012).	Medium
In the vicinity of the Handsacre east culvert crossing, and the Handsacre West culvert extension crossing Volume 5 Map WR-01-038, D8 and C8	A temporary site access/haul road and temporary earthworks stockpiles will be located in areas at a low, medium and high risk of surface water flooding.	High

8.2.13 There are eleven locations of temporary design elements in this study area which have been identified to be at risk from surface water flooding from the Environment Agency FMfSW. A conservative approach has been taken in categorising risk as outlined earlier in this section. Therefore, in line with the flood risk category matrix (Table 1) a high risk of surface water flooding has been categorised at six locations, a medium risk at four locations and a low risk at one location.

8.2.14 Construction and satellite compounds have the potential to interrupt surface water flow paths. However, there are no satellite compounds in this study area that will interrupt surface water flow paths which are identified on the Environment Agency FMfSW.

8.2.15 In line with the risk category matrix provided in Table 1, all other locations for temporary works within this study area are classed to be at no risk from surface water flooding.

8.2.16 The works will be completed in line with the CoCP and hence the design of the temporary works will prevent an unacceptable level of surface water flood risk on site.

8.2.17 Temporary works not identified to be at risk on the FMfSW also have the potential to increase flood risk from this source in neighbouring areas as a result of reduced

ground permeability. Therefore, in line with the draft CoCP, surface water will be managed at all locations of temporary works, including areas not identified to be at risk from surface water in Table 8. This will ensure that the temporary works are at an acceptable level of risk and do not cause an increased risk elsewhere from surface water flooding.

8.3 Groundwater

8.3.1 Developments may increase the risk of groundwater flooding where a barrier to groundwater flow in constructed across the natural flow path. The presence of such a barrier may impede groundwater flow causing levels to increase up gradient; if these levels rise to the ground surface groundwater flooding may occur.

8.3.2 A review of the Proposed Scheme in this CFA does not indicate that any barriers to flow will be introduced that will affect a significant aquifer thickness.

8.3.3 It is therefore concluded that the scheme will not increase the risk of groundwater flooding.

8.4 Sewer systems

8.4.1 The route will cross the sewer network at two locations and will be located within approximately 120m of an inspection cover. However, topography in the area indicates that there are no flow paths for flooding to the Proposed Scheme from this source.

8.4.2 At three locations the route crosses the sewer network and there are inspection covers at the location of the route. At these locations however the inspection covers will be relocated to the foot of the embankment of the route. Flood water either side of the route would flow along the track drainage channels and into the associated watercourse (Volume 5: Map WR-05-063, G5, SWC-CFA22-006).

8.4.3 The works will be completed in line with the CoCP and hence will ensure that the Proposed Scheme and neighbouring areas will not be at an increased flood risk from this source. One such measure outlined in the draft CoCP requires the removal or stopping and sealing of drains and sewers taken out of use. Similarly as outlined in the draft CoCP, precautions will also be taken to prevent damage to services and to avoid pollution during service diversions, excavations and ground penetration.

8.5 Artificial sources

8.5.1 At locations where the route crosses canals or areas at risk of flooding as a result of reservoir failure, there is potential that the Proposed Scheme may either increase risk from this source, or divert flood water causing new areas to be put at risk.

Reservoirs

8.5.2 The Environment Agency reservoir inundation maps indicate that if Swinfen Lake fails, flooding would occur at the location and surrounding area of the Cappers Lane viaduct (Volume 5: Map WR-01-037, E5). There are no other design elements in this area at risk of flooding from this source. The temporary works at risk are Cappers Lane viaduct (north) compound, Cappers Lane viaduct (west) compound and a temporary site access/haul route and fencing. The reservoir inundation mapping covers a greater

extent than the river Flood Zone mapping and therefore there is potential that the Proposed Scheme may slightly alter flow paths at this location.

8.5.3 As outline in Section 6.6, if Stowe Pool or Minster Pool were to fail, flooding would occur at the location and surrounding area of the Pyford Brook viaducts (Volume 5Map WR-01-037, G5). The other design elements at risk in this location are the Pyford Brook east embankment and the Pyford Brook west embankment. The temporary work elements at risk are a site access/haul road, fencing, and a temporary bridge/culvert. The reservoir inundation mapping covers a greater extent than the river Flood Zone mapping and therefore there is potential that the Proposed Scheme may slightly alter flow paths at this location.

8.5.4 In line with the risk category matrix (Table 1) the flood risk to all elements of the Proposed Scheme from reservoir failure is considered low.

8.5.5 The CoCP outlines that areas at risk of flooding should be considered when planning sites and storing materials. The flood risk areas are likely to be taken from the river flood risk maps, however at the locations at risk from reservoir inundation in this study area, the reservoir inundation maps are greater than the areas at risk from river flooding. Therefore, the management of the temporary works at risk from this source should consider the impact of risk of flooding as a result of reservoir failure, although it is not anticipated that these proposed works would have a significant impact on flood flow routes and hence flood risk to other receptors.

8.5.6 There are no other locations within this study area that are at risk of flooding from reservoir failure as shown on the Environment Agency reservoir inundation maps. It is therefore concluded that the Proposed Scheme, including the route, other design elements and temporary works, will be at a low risk of flooding from this source (Table 1) and will not result in an increased risk elsewhere.

Canals

8.5.7 The proposed route involves development that crosses the Wyrley and Essington Canal (Volume 5: Map WR-01-037, G5) in this study area.

8.5.8 The other design elements to the north of this canal, specifically a balancing pond and access road are at risk should overtopping occur.

8.5.9 The temporary works at risk are those at Cappers Lane viaduct (north) compound, Cappers Lane viaduct (west) compound and a site access route/haul route. Cappers Lane viaduct (west) compound would be at a higher elevation than the canal, and hence is not considered to be at risk. Cappers Lane viaduct (north) compound is located at a lower elevation than the minor embankment to the south of the canal and hence will be at risk following overtopping from the canal. There are no other temporary works at risk from this source of flooding.

8.5.10 The proposed route involves development that crosses the Trent and Mersey Canal (Volume 5: Map WR-01-037, G5 and F5) in this study area.

8.5.11 The other design elements to the south of this canal, specifically two balancing ponds and associated access roads, Pyford Brook east embankment and Pyford Brook west embankment are at risk should overtopping occur.

8.5.12 The temporary works at risk are those at Trent and Mersey Canal East viaducts (south-east and north-east) compounds, Trent and Mersey Canal West viaducts (south-west and north-west) compounds and a temporary site access route/haul route. Trent and Mersey Canal East viaducts (south-east) compound and Trent and Mersey canal West viaducts (south-west) compound would be at a higher elevation than the canal, and hence is not considered to be at risk. Trent and Mersey Canal East viaducts (north-east) compound and Trent and Mersey canal West viaducts (north-west) compound would be located at a lower elevation than this minor embankment to the north of the canal and hence will be at risk following overtopping from the canal. There are no other temporary works at risk from this source of flooding.

8.5.13 The canal crossing requires a minimum soffit height for navigational purposes and this soffit would be sufficiently high to prevent any impact on flow. Similarly the works will be undertaken in line with the CoCP and hence will ensure the works are at an acceptable level of risk and that the Proposed Scheme will not cause an increased risk elsewhere.

8.5.14 In line with the risk category matrix in Table 1, the risk to the other design elements and the temporary works is low. These works will be completed in line with the CoCP and hence will not impact on flood risk from this source.

8.6 Summary

8.6.1 The Proposed Scheme will be located in areas at risk from river flooding, including at eight watercourse crossings where a very high risk has been assigned. However, the hydraulic modelling completed at these eight locations identifies that at seven of the crossings the impact of the Proposed Scheme is negligible. At one crossing, Fulfen Wood culvert, the Proposed Scheme would have a minor impact on river flood risk. However, at this crossing modelling has shown that mitigation can be provided upstream of this crossing to reduce the change to a negligible impact.

8.6.2 All elements of the Proposed Scheme will cross areas susceptible to surface water flooding. In general, at each of the areas the risk ranges from low to high, although as a conservative approach the highest level of risk has been assigned resulting in many of the areas being categorised as being at a high risk from surface water flooding. However, the Proposed Scheme will mitigate surface water run-off to ensure that the works are at an acceptable level of flood risk and do not result in an increased risk elsewhere.

8.6.3 The Proposed Scheme will involve development within an area at a low risk from groundwater flooding. However, the design involves measures to ensure that the development is an acceptable level of risk and that the Proposed Scheme does not increase flood risk from this source.

8.6.4 There is a medium risk to the Proposed Scheme including the route, other design elements and the temporary works of flooding from the sewer network. However, the works will be completed in line with the CoCP and hence will ensure that the Proposed Scheme and neighbouring areas will not be at an increased flood risk from this source.

8.6.5 Water levels within canals are continually maintained and hence the chance of overtopping and thus flood risk from this source is considered low. Similarly due to the

strict monitoring and maintenance requirements, the risk of reservoir flooding to the development is considered low. The design ensures that the Proposed Scheme will not result in an increased risk from this source both to the development and elsewhere.

9 Conclusions

9.1.1 The Proposed Scheme, including the route, other design elements and the temporary works, are to be located within areas at risk from flooding from a range of sources. However, the temporary works will be designed to and will follow the CoCP such that development will be at an acceptable level of risk and will not cause an increased risk elsewhere. The proposed mitigation as part of the permanent works will also ensure that the Proposed Scheme will be at an acceptable level of flood risk and will not result in an increased risk elsewhere.

9.1.2 The magnitude of impact and significance of effects have been based on the Environmental Impact Assessment (EIA) Scope and Methodology Report (SMR, see Volume 5: Appendix CT-001-000/1). Table 9 shows a summary of the sources of flood risk within this study area and the associated magnitude of impact and significance of effects.

9.1.3 In terms of river flooding, the magnitude of impact in this study area of the Proposed Scheme with the floodplain replacement storage is negligible and significance of effects neutral.

9.1.4 Although there are areas of the Proposed Scheme at no, low, medium and high risk from surface water flooding, overall the risk from this source is categorised as high, as a conservative approach. However, the overall magnitude of impact is negligible and the significance is neutral. This has been determined because the design of the permanent works will be in line with the design criteria outlined in Section 12 of this report and that the temporary and construction works assessed as part of this FRA are in line with the draft CoCP.

9.1.5 Groundwater flood risk has been assessed as low within the CFA.

9.1.6 The risk from sewer flooding is medium within this study area, and the overall magnitude is negligible with a neutral significance. This has been determined because the design of the permanent works will be in line with the design criteria outlined in Section 12 of this report and that the temporary and construction works assessed as part of this FRA are in line with the draft CoCP.

9.1.7 In this study area artificial sources of flooding (both from reservoir failure and canals) have also been categorised as low, resulting in a low significance of effect.

Table 9: Summary of Flood Risk Receptors showing the overall magnitude of impact and significance of effects

Flood risk receptor	Risk category	Magnitude of impact	Significance of effects
Areas at risk from river flooding	Very High	Negligible	Neutral
Areas at risk from surface water flooding	High	Negligible	Neutral
Areas at risk from groundwater flooding	Low	Negligible	Neutral
Areas at risk from drainage and sewer flooding	Medium	Negligible	Neutral
Areas at risk of flooding from artificial sources	Low	Negligible	Neutral

9.2 Residual flood risk to the Proposed Scheme

9.2.1 Residual flood risks arise in situations that are not included in standard design scenarios, for example when a culvert becomes blocked causing flooding upstream. All design is generally undertaken assuming that existing infrastructure is functioning under normal conditions. Consequently, there may be areas where the potential severity of flooding may exceed the design standard under certain circumstances.

Residual flood risks from river sources

Cappers Lane viaduct

9.2.2 There is one existing hydraulic structure downstream of the Cappers Lane viaduct. However, the viaduct would be at a significant height above the floodplain, and hence the residual risks of flooding over and above the design event, and the risk of blockage, would not be significant.

Fulfen Wood culvert

9.2.3 There are two existing structures in the vicinity of the Fulfen Wood culvert. These structures are a railway crossing upstream of the proposed culvert and the Coventry Canal crossing downstream of the proposed culvert. The existing upstream structure is located upstream of the Proposed Scheme and, therefore, blockage at this structure will not lead to any significant increase in the risk of flooding to the Proposed Scheme. Depending on the constriction on flow caused by the railway crossing, any failure of the structure could potentially cause a minor increase in flood levels at the location of the Proposed Scheme. There is a potential that blockage at the downstream Coventry Canal crossing will impact on flood levels at the location of the Proposed Scheme. Even though the risk of flooding from a downstream blockage is unknown, the track would be at a significant height above the floodplain and hence the risk to the track is considered low.

Mare Brook South culvert

9.2.4 There is one hydraulic structure in the vicinity of Mare Brook south culvert. This existing structure is the A38 road crossing and is located downstream of the Proposed Scheme. There is potential that blockage at this existing road crossing will impact on flood levels at the location of the Proposed Scheme. Even though the risk of flooding from a downstream blockage is unknown, the track would be at a significant height above the floodplain and hence the risk to the track is considered low.

Mare Brook North culvert

9.2.5 There is one hydraulic structure in the vicinity of Mare Brook north culvert. This existing structure is the A38 road crossing and is located downstream of the Proposed Scheme. There is potential that blockage at this existing road crossing will impact on flood levels at the location of the Proposed Scheme. Even though the risk of flooding from a downstream blockage is unknown, the track would be at a significant height above the floodplain and hence the risk to the track is considered low.

Pyford Brook viaducts

9.2.6 There are existing hydraulic structures in the vicinity of the Pyford Brook viaducts. The existing structures are the Wyrley and Essington Canal crossing, and also the Wood

End Lane road crossing, both upstream of the Proposed Scheme. However, the viaduct would be at a significant height above the floodplain, and hence the residual risks of flooding over and above the design event, and the risk of blockage, would not be significant.

Bourne Brook viaduct

9.2.7 There are existing hydraulic structures in the vicinity of the Bourne Brook viaduct. The existing structures are a railway crossing, and also the Lichfield Road Crossing, both located upstream of the Proposed Scheme. However, the viaduct would be at a significant height above the floodplain, and hence the residual risks of flooding over and above the design event, and the risk of blockage, would not be significant

Handsacre East culvert

9.2.8 There are hydraulic structures in the vicinity of the Handsacre East culvert. The existing structures are the B5014 road crossing, and also the Trent and Mersey Canal crossing. At this location however, the track would be at a significant height above the floodplain so that the risk of flooding from failure or blockage of these structures would be considered low.

Handsacre West culvert extension

9.2.9 There are hydraulic structures in the vicinity of the Handsacre west culvert extension. The existing structures are the B5014 road crossing, and also the Trent and Mersey Canal crossing. At this location however, the track would be at a significant height above the floodplain so that the risk of flooding from failure or blockage of these structures would be considered low.

Residual flood risks from surface water sources and minor watercourses

9.2.10 All culverts within the Proposed Scheme are designed with a minimum internal headroom of 300mm above the design flood water level to minimise the risk of blockage. Therefore, there are not expected to be any significant increases in risk of flooding at dry valley crossings arising from potential blockage of culverts.

Residual flood risks from groundwater

9.2.11 Groundwater levels rise and fall relatively slowly, and therefore any change in the risk of flooding from this source would be the result of below ground intervention. The risk of groundwater flooding already considered in this FRA presents an absolute risk, and there are no significant residual risks arising from this source.

Residual flood risks from the sewer network

9.2.12 Blockage of underground sewer networks can cause surcharge and associated flooding. At locations where the existing sewer infrastructure will need diverting, any replacement infrastructure would be to at least the same standard as existing. Consequently, no additional residual risk to the Proposed Scheme would be expected as a result of drainage system failure.

Residual flood risks from artificial and surface sources

9.2.13 This assessment considers the potential for total failure of reservoirs and canals, which is deemed to be the most extreme case of flooding from these sources.

Therefore, it is considered that there are no further residual risks from artificial sources of flood risk.

9.3 Residual effects of the Proposed Scheme on flood risk

9.3.1 All culverts within the Proposed Scheme will be designed to convey the 1 in 100 year (1% annual probability) flow including an allowance for climate change with a minimum internal headroom of 300mm above the design flood water level (to minimise the risk of blockage). Consequently, there would be negligible increase in upstream residual flood risks arising from the introduction of culverts within the Proposed Scheme.

9.3.2 All viaducts within the Proposed Scheme will also be designed to allow the 1 in 100 (1%) annual probability flow with an allowance for climate change to pass underneath. As a minimum the design will ensure a 600mm freeboard will be provided to the bridge soffits above this level, and on main rivers where possible, a freeboard of 1m will be allowed. These freeboards will allow for debris and hence prevent a significant increase in residual risk in upstream areas as a result of the Proposed Scheme.

10 References

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